NO MORE DRILLING IN THE DARK:
Exposing the Hazards of Natural Gas Production and Protecting America's Drinking Water and Wildlife Habitats

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No More Drilling in the Dark: Exposing the Hazards of Natural Gas Production and Protecting America's Drinking Water and Wildlife Habitats
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Prepared by National Wildlife Federation Staff:
Richard Forrest, Energy Specialist

Larry J. Schweiger
President and Chief Executive Officer

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Executive Summary

In recent years, there has been explosive growth in industry activities to extract natural gas from shale formations located throughout America. While the growth of the natural gas industry has provided some economic benefits to local economies, it has also been accompanied by growing public fears. In particular, concern and opposition have centered on the process of hydraulic fracturing ("fracking") used to extract shale gas.

This report provides an overview of unconventional gas drilling and the key concerns and potential threats that such drilling raises for America's land, water, air and wildlife. It also provides a number of recommendations for addressing and reducing related environmental impacts.

While many potential impacts remain unknown, there have been documented cases of pollution and impacts on habitats that raise serious concerns. Fracking chemicals and methane have contaminated underground water resources. The clearing of forests for the construction of drilling pads and access roads has fragmented habitats and led to silt runoff. Drilling accidents have led to pollution of streams and other water bodies. Fracking fluids have been shown to be harmful or deadly for plants and animals. Exhaust from drilling-related machinery has worsened air pollution. Methane leakages have contributed to increased emissions of greenhouse gases in the atmosphere, which scientists link to climate change and ocean acidification.

While some state and federal agencies have begun working to respond to the growth of the industry and provide improved regulation and oversight, much more needs to be done. The National Wildlife Federation recommends a number of actions to ensure that the development of unconventional natural gas resources is pursued in an environmentally responsible manner. Needed improvements to regulatory frameworks and industry practices include greater transparency, improved research and monitoring, eliminating existing loopholes and exemptions from environmental laws, establishing mitigation and compensation mechanisms, and improving practices to reduce impacts on water resources and habitats.

To the extent that natural gas can be substituted for coal and oil — and especially if its use can help us avoid energy sources such as tar sands and oil from risky offshore drilling — there can be some environmental benefits. Nevertheless, natural gas produces greenhouse gas emissions — and is a limited fossil fuel resource that will someday be depleted. It is therefore no more than a temporary stopgap as our nation makes a necessary transition to renewable energy sources.

America should choose extraction practices that do not endanger the long-term integrity and health of our forests, rivers and grasslands, and the wildlife species that depend on them. The National Wildlife Federation will remain committed to educating the public and lawmakers about the risks posed by unconventional natural gas exploitation, and we will work for the enactment of prudent regulations to safeguard our nation's land, air, water and wildlife.


Courtesy of EcoFlight

Introduction

Over the past few years, a shale gas revolution has swept America. New applications of drilling technologies have made it feasible to extract large quantities of natural gas from "unconventional" resources trapped in shale rock formations found throughout the United States.[1] These natural gas-rich shale formations are found thousands of feet below the surface — often beneath rural backyards, fields and forests — and in places, such as Arkansas and Michigan, that have never before seen intensive gas drilling. The largest of these deposits is the Marcellus Shale, which underlies much of New York, Ohio, Pennsylvania and West Virginia.

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While increasing the extraction of natural gas can help to provide energy for America's future, the new approach to natural gas drilling poses new risks to our environment. There are many reasons for concern. There have been reports of flammable methane migrating into drinking water supplies located near active drilling sites. Spills of drilling fluids and contaminated water are believed to have killed livestock, as well as fish and other aquatic life in ponds and streams. The construction of roads, drilling pads and pipelines — and enormous numbers of truck trips associated with drilling activities on once quiet byways — are impacting rural communities and affecting America's landscape. So while the shale gas boom has excited investors, it has also concerned residents of swiftly industrializing rural areas and those who live and recreate downstream.

Indeed, unconventional natural gas exploitation has become very controversial, with strong views staked out on opposing sides. One key technology, high-volume hydraulic fracturing — also known as "fracking" — has become the subject of especially heated debate. Residents have risen up in protest in some communities to protect their water and lands from the potential impacts from fracking operations. Natural gas proponents, in turn, claim that such concerns are exaggerated. Unfortunately, information about impacts has not been systematically collected, and scientific research has not dispelled such fears. The concerns over fracking have led to the practice being banned in the Canadian province of Quebec[2] and France;[3] the state of New York also had a temporary de facto moratorium on fracking, and as of August 2011 was in the process of establishing new regulations to guide future drilling operations.

Unfortunately, fear is fed by a lack of certainty — and much about the effects of shale gas drilling, especially the long-term effects, remain unknown. Fracking takes place in deep subterranean strata, beyond the ability of governments, scientists and citizens to closely monitor — or for industry to remediate contamination that may occur. For those who are concerned with the environmental impact of these new large-scale drilling activities, a key concern is that comprehensive baseline research, surveys and monitoring studies are not being conducted. Unless safeguards are put in place, tens of thousands of wells could be drilled in various regions throughout our nation before we understand how this will affect our land, water, air, and wildlife.

Every approach to energy development has its own risks and potential impacts. When compared to coal and oil, unconventional natural gas extraction may be somewhat less polluting — but only if it is pursued in a responsible and cautious way, avoiding the most damaging practices and impacts.

As America charts a course for its energy future, decisions must be based on a full consideration of the impacts of energy development activities. This requires full transparency, intensive research, and comprehensive monitoring. The situation is complicated by the fact that the impacts of unconventional natural gas production are wide-ranging and complex; no single indicator can capture the full impacts. The issue is so complicated that in July 2011, the Marcellus Shale Advisory Commission, which had been established to advise the governor of Pennsylvania, made 96 different recommendations — 43 concerning the environment — for improving the regulation of natural gas development.[4]

This report provides an overview of unconventional gas drilling and the key concerns and potential threats that it raises for America's land, water, air and wildlife. It also provides a number of recommendations for addressing and minimizing the environmental impacts of unconventional natural gas development. By adopting a sensible system of regulatory safeguards, the impact of shale gas extraction can be better understood and managed.

It is time for the entire process to be better understood, open to public scrutiny, and guided by sound oversight and environmental protections.

UNITED STATES SHALE GAS PLAYS

FIGURE 1: Areas of shale gas resources (known in the industry as "plays") are widely distributed throughout the United States. (Source: U.S. Energy Information Administration)

Unconventional Natural Gas Extraction — What it Involves

Hydraulic fracturing — or "fracking" — is a process in which large volumes of fluids — a mixture of water, sand and chemicals — are injected at high pressure underground to fracture or crack open layers of shale rock. This stimulates the natural gas, which is trapped in tiny pores in the rock, to flow out and be captured aboveground at the wellhead.

Combined with horizontal drilling (also known as directional drilling), fracking allows for the extraction of large volumes of previously unrecoverable natural gas resources. Many of these resources are in areas that previously had not experienced intensive natural gas extraction, and the fees paid to owners of subsurface mineral rights can provide attractive sources of income for some. Drilling operations can also be a significant, although potentially short-term, source of jobs and economic development in areas that are usually rural and lacking other economic development opportunities.

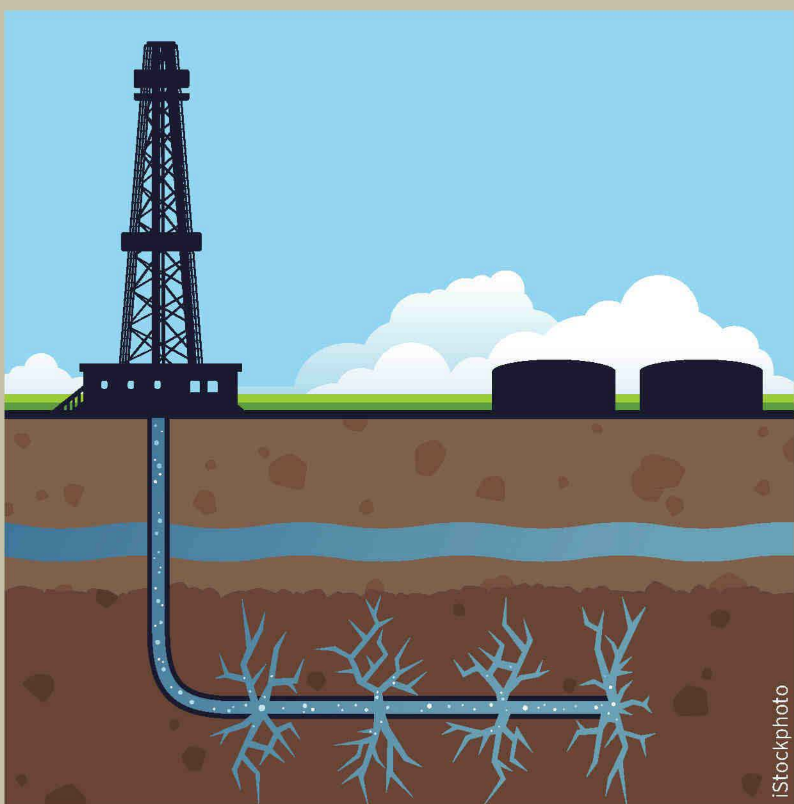


FIGURE 2: Hydraulic fracturing (fracking) gas drilling concept illustration.

Fracturing of the shale can take place 3,000-15,000 feet below the surface. As shown in the schematic image below, wells that are drilled down to a level of thousands of feet can traverse natural aquifers that lie closer to the surface (typically less than one thousand feet below the surface) and which people may tap into through wells in order to obtain water for drinking, bathing, and agricultural uses. The process of drilling through these water tables can allow pollution to enter such subsurface water resources, especially if well casings (the steel pipes lining the well hole) rupture or otherwise fail.

Although fracking takes place below the water table, the drilling necessarily requires puncturing through layers of rock and water closer to the surface. To claim that aquifers cannot be impacted is therefore a logical impossibility; failure of a well casing at the depth of an aquifer would allow drilling fluids to enter the aquifer. In addition, the high pressures involved in the fracking process can put severe stresses on the well casings, cement and other components of a well. Hydraulic fracturing may therefore lead to more well failures (cracking and rupturing and release of gases and fluids) compared to non-fracked wells, with consequences for safety as well as air and water pollution.

The process of exploiting unconventional natural gas resources involves a number of phases, beginning with aerial and seismic exploration to determine promising drilling sites; planning and well siting; drilling of the well using a temporary drilling derrick; and "well development" or "stimulation" —

when the hydraulic fracturing process takes place — to release the natural gas trapped in the shale. This is followed by the so-called "completion phase," in which the derrick is removed and a mechanism called a production wellhead (or "Christmas tree") is installed to collect the natural gas which flows out of the underground rock over a period of months and years. Various stages throughout this process involve the collection and handling of waste water and chemicals. The natural gas extracted also needs to be transported through pipelines to distant markets and processing facilities. A single well may be repeatedly stimulated through multiple hydraulic fracturing operations and new drilling holes may be drilled in different directions, but once a well has reached the end of its productive life, it is closed.

FRACKING FLUIDS

Fracking fluids are comprised mainly of water and sand (the sand serves as a "proppant," holding open the fissures created when the shale is fractured); a small percentage of the fracking fluid is made up of various chemicals. These chemicals may include acids (such as hydrochloric acid), biocides, corrosion inhibitors (such as the highly toxic chemical methanol), gelling agents (such as ethylene glycol), and surfactants (such as naphthalene and isopropyl alcohol).[5] The chemicals used in fracking may include known toxic chemicals, including carcinogens.[6]

The specific mixture of chemicals used depends on the geological and other conditions of the drilling site. Companies have tended to not release full information on the specific chemical mixtures they use; companies may wish to protect their proprietary corporate brands of mixtures of chemicals as trade secrets. Drilling companies may also use "off-the-shelf" chemical mixtures supplied by vendors, without knowing exactly what chemicals they include.

There would appear to be no legitimate reason to not fully disclose all of the chemicals used in fracking operations. Some companies are on record in support of full disclosure, and recognize the importance of transparency in gaining public trust.[7]

Some chemicals have many alternative names, complicating regulation and monitoring activities. For example, the website FracFocus lists 28 names in use for the chemical ethylene glycol,[8] which is a common component of fracking fluids and which is known for its use as antifreeze. The sheer number of chemicals and their combinations are daunting; a report for the U.S. House of Representatives Committee on Energy and Commerce found that between 2005 and 2009, fourteen oil and gas service companies that responded to a request for information had "used more than 2,500 hydraulic fracturing products containing 750 chemicals and other components."[9]

Many of the chemicals used are hazardous to humans and wildlife. According to the House committee report, "the hydraulic fracturing companies used 95 products containing 13 different carcinogens."[10] Although the toxic components of fracking fluid are used in dilute concentrations, and the health impacts of any pollutants depend on concentrations and length of exposure, the fate of fracking fluids underground is almost completely unstudied.

The federal Safe Water Drinking Act (SWDA) of 1974 was created in part for the Environmental Protection Agency to control materials that are injected underground and to therefore protect underground sources of drinking water. Unfortunately, injections for the purpose of hydraulic fracturing were specifically exempted from such regulation under an amendment to the Energy Policy Act of 2005.[11] The use of diesel fuels for fracking remained subject to SWDA regulation, however; despite this, as well as an additional pledge by key drilling companies to not use diesel fuels in fracking operations, members of the U.S. House of Representatives Committee on Energy & Commerce notified the EPA that an investigation had found that "Between 2005 and 2009, oil and gas service companies injected 32.2 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel in wells in 19 states."[12]

Once the fracturing occurs, a substantial proportion — anywhere from 15 to 90 percent[13] — of the injected water flows back to the surface (such water is known as "flowback water"); it therefore contains the chemicals that were originally injected as fracking fluid — as well as other components, including radioactive isotopes, that can leach out of the rock layers that the water has flowed through. "Produced water," which is usually highly saline water that naturally occurs underground, may also flow out of the well bore as a result of the drilling and stimulation of the well, bringing with it impurities. Some of the flowback water and produced water can be reused in certain operations, but often the water is too saline to reuse. This water may be reinjected into the ground in some areas having appropriate geological formations to accommodate such reinjections.[14] If not reinjected, the waste water is normally held in an open pit near the drilling pad, or trucked to wastewater treatment plants — although in some locations, particularly in the western U.S., produced water is also discharged directly into streams.[15]

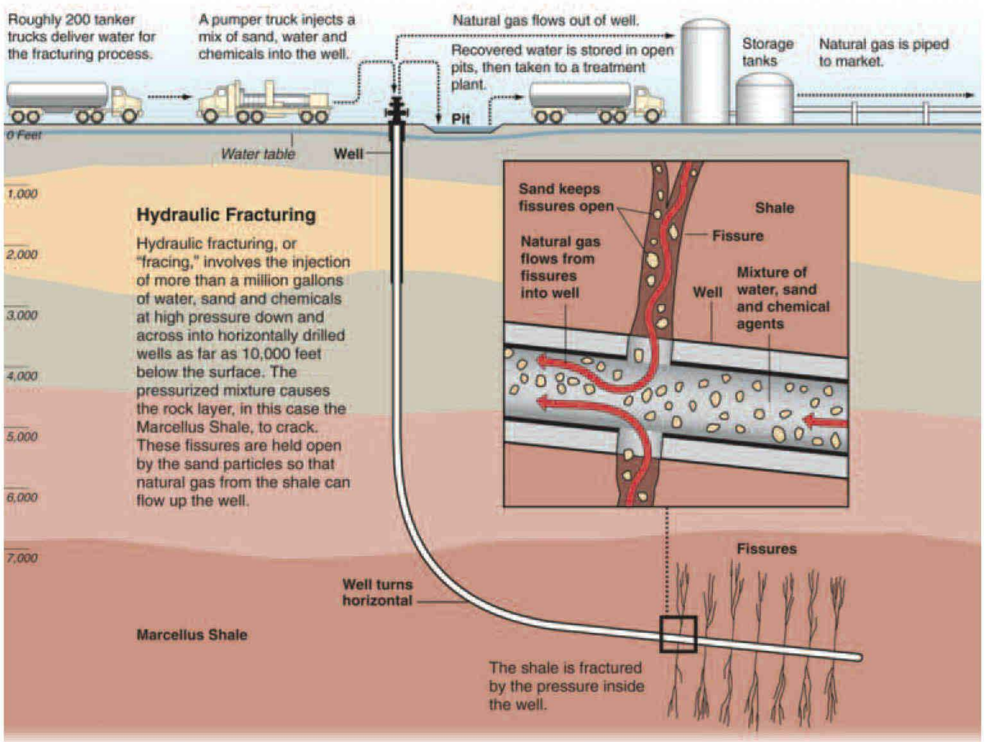


FIGURE 3: Detailed schematic view of the hydraulic fracturing process in the Marcellus Shale, where shale gas resources are concentrated roughly 7,000 feet below the surface; shale gas may be extracted from other depths in other regions. (Note that "fracing" is an alternative spelling for the now more common "fracking.")

(Diagram by Al Granberg; Creative Commons image courtesy of ProPublica.)

Impacts on Water Quality and Supply

Perhaps the most controversial and potentially damaging risks from unconventional natural gas exploitation are the potential impacts on water.

Fears of water pollution related to fracking have been the central focus of opposition by many affected communities. Newspapers and websites have reported numerous cases in which drinking water has likely been impacted by natural gas drilling operations. There are also multiple incidents where drilling companies have paid fines or compensation for impacts on water quality — although in many such cases they have done so without formally admitting legal liability. It is difficult to draw causal links between a company's drilling operations and underground water contamination, especially considering that subterranean geological features and hydrologic flows lie far beyond the ability of investigators to examine directly. For chemicals placed underground without markers, it may take decades to identify the source of underground pollution plumes. It may not be possible to clearly link cause and effect in such cases, which hampers proper investigations and the imposition of legal remedies for problems that may arise.

Some in the natural gas industry have claimed that there have been no documented cases of fracking fluid impacting water sources. Nevertheless, in early August 2011, news articles publicized a 1987 report by the U.S. Environmental Protection Agency documenting a case in which fracking chemicals were found to have contaminated a drinking water well in West Virginia in 1984.[16] The lack of documentation of other similar cases appears to be the result of a lack of access to information; according to the *New York Times*, researchers "were unable to investigate many suspected cases" of similar potential contamination, "because their details were sealed from the public when energy companies settled lawsuits with landowners."[17]

The overall process of drilling for unconventional natural gas, which involves fracking for as much as ninety percent of wells,[18] has involved various kinds of stresses on America's water resources.

SURFACE WATER USE AND WITHDRAWALS

Each time that a well is hydraulically fractured, hundreds of thousands of gallons of water are required. As this procedure may be carried out many times, each well may therefore require several million gallons of water for fracking operations.[19]

This water normally must be withdrawn from nearby wells, lakes, rivers, or industrial or municipal water systems. Large-scale water withdrawals may result in reducing the flow of streams below levels acceptable for fish (such as brook trout) and other wildlife. Such lowered stream flows can also lead to higher water temperatures and other impacts on wildlife habitat conditions. Water usage is of particular concern in areas experiencing drought, including the Eagle Ford shale gas region in Texas, where officials and residents have been concerned that the use of limited water resources for natural gas extraction activities will result in insufficient water for other important uses.[20]

METHANE MIGRATION INTO GROUNDWATER

The process of releasing natural gas from layers of rock through fracking is believed to potentially lead to the migration of gases into other geological layers, including aquifers. Groundwater near drilling wells has in fact been contaminated with methane,

the main component of natural gas. This can pose a fire and explosion hazard; the health risks of drinking methane-contaminated water remain unknown.

While some cases of methane in water may be due to other causes, a peer-reviewed study by researchers from Duke University found that water from wells closer to active natural gas drilling sites had higher concentrations of methane.[21] The researchers sampled water from wells and found that "Methane concentrations were 17-times higher on average…in shallow wells from active drilling and extraction areas than in wells from nonactive areas." This study was conducted in limited areas of New York and Pennsylvania, and conditions in other areas and states remain unknown.

Migration of methane into groundwater can be caused by the failure of drilling well casings. In 2009, the State of Pennsylvania Department of Environmental Protection (DEP) issued a Notice of Violation to Cabot Oil and Gas Company related to their operations in Dimock, Pennsylvania; an investigation by the DEP "revealed that Cabot had caused or allowed [natural] gas from lower formations to enter fresh groundwater."[22] Cabot was requested to provide free methane detectors and alternative water supplies for several affected families, was required to pay a $4.1 million settlement,[23] and had its drilling activities in the area suspended. The DEP also cited improper well casing and cementing as a cause of the migration into groundwater of shallow, non-shale natural gas in an incident in Bradford County, Pennsylvania, which led to the contamination of drinking water used by 16 families. For this incident, the company Chesapeake Energy was fined over $1 million.[24] Many cases in which groundwater resources have been impacted by methane migration involve wells that would not have been drilled if fracking were not a part of the overall drilling operation, making such drilling profitable.

Clearly, the mechanisms and impacts of such underground gas migration call for a greatly enhanced program of research, monitoring, and precautionary safeguards to avoid impacts on underground water sources that are used by so many Americans.

OTHER SUBSURFACE WATER QUALITY IMPACTS

While comprehensive studies of the impact of unconventional natural gas extraction activities on water quality have not been undertaken, impacts are quite likely to emerge over time, given the nature of the geological pathways that exist or that are created as a result of fracking operations. A study by the New York City Department of Environmental Protection[25] (NYC DEP) concluded that layers of rock normally serve as a natural barrier between shale formations and the more shallow aquifers that can be used for drinking water. However,

> "This protection may be compromised during gas well drilling and stimulation. Casing or grouting failures, existing subsurface fractures, and fractures created during stimulation that propagate beyond the target formation can create or enhance hydraulic pathways between previously isolated formations. These pathways can allow drilling and fracturing chemicals or formation material (e.g., hydrocarbons or saline water) to contaminate shallow groundwater and surface water resources.
>
> "…Subsurface conditions are not static, and faults can develop or widen over time. Natural gas development activities may increase the likelihood of movement of existing, naturally occurring faults. Induced seismicity is known to be associated with injection wells, and has reportedly been linked with hydrofracturing operations."

NYC DEP also found that wells "may result in contact with saline aquifers or formations that contain hydrocarbons, heavy metals, radionuclides or other potential contaminants."[26]

Underground water does not always stay underground; it may come to the surface in springs that lead to water bodies where wildlife species drink, feed or breed. Water pumped out of the ground through wells may also be applied to agricultural fields inhabited or frequented by wildlife species. This highlights the need to address the risks that natural gas extraction may create new hydraulic pathways allowing underground radioactive or other toxic material to be brought to the surface.

OTHER SURFACE WATER IMPACTS

Unconventional natural gas drilling operations create waste water, including fracking fluids, flowback water and produced water. This waste water needs to be handled in a way that will not impact surface water, such as lakes and rivers. There have been reports of inappropriate disposal of high-salinity produced water, which entered rivers and streams. Waste water from drilling operations is often held in large open air waste pits, or "evaporation pits," which may leak as a result of improper linings, ruptures, fires and other accidents.

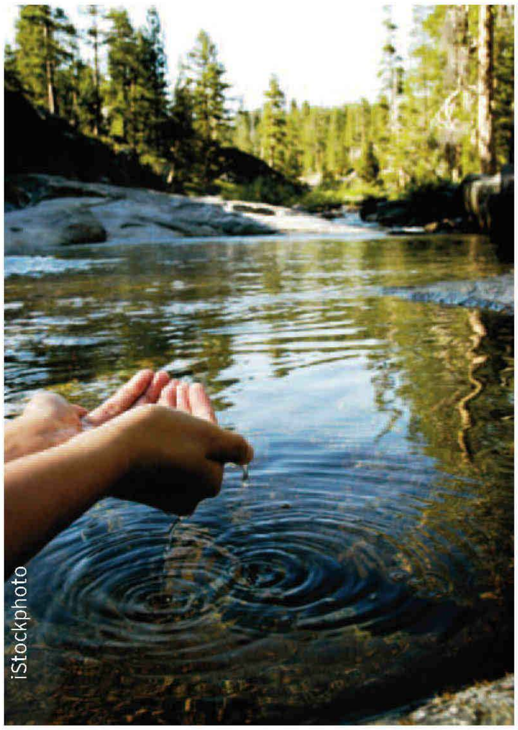
Even when wastewater is handled in accordance with regulations, it may be transported to wastewater treatment facilities that have been built mainly to treat household or industrial waste. The components of waste water from drilling operations are likely to be different from other wastes, and can include salts, heavy metals and radionuclides, which may therefore not be properly treated by such treatment facilities, ending up in public waterways.

The drilling pad, which needs to accommodate dozens of tanker trucks and other machinery, requires an area that needs to be cleared and leveled. Soil disturbed during this process may flow into rivers and lakes when there is a rainstorm, as soil denuded of vegetation can be washed down hillsides. This can lead to the silting of streams, which can impact fish and other organisms. Although there are some regulations established to address such stormwater flows in general, including the stormwater permitting provisions under the federal Clean Water Act,[27] construction activities for oil and gas drilling operations have actually been exempted from the Clean Water Act,[28] under what has come to be known as the "Storm Water Runoff Loophole."

Drilling operations also involve heavy machinery, which may require lubricants, diesel fuel and other fluids that may spill and contaminate land and water in cases of accidents or improper handling. Accidents of many kinds — including drilling rig fires and explosions, spills, blowouts, failure of retention ponds, and overturned trucks — have released pollution that can flow into water bodies. A study by the Massachusetts Institute of Technology summarized the readily available accounts of pollution problems associated with natural gas drilling; this report identified 43 reports of pollution-related incidents, some of which involved fish kills and other impacts on wetlands and aquatic wildlife.[29] There are many cases of water contamination in which fracking has been suspected as a cause;[30] in many such cases, proper scientific studies do not appear to have been performed, in part due to lack of legal mandates and funds available to those affected.

Other energy technologies also have significant impacts on water. In comparison to other energy technologies, the extraction of natural gas in general requires less water per unit of usable energy produced. When natural gas is used in electricity generation facilities, less water is consumed than in the case of coal-fired plants or nuclear power plants.[31] In terms of unconventional natural gas, a recent study concluded that "natural gas produced by hydraulic fracturing consumes seven times more water than conventional gas extraction but roughly the same amount of water as conventional oil drilling."[32] When compared to the production of ethanol and other biofuels, unconventional natural gas production requires significantly less water on average — although these demands on water resources may still have quite significant impacts, especially in arid regions in the western U.S.

The water impacts of unconventional natural gas drilling may be very localized; however, given the uncertainties of underground hydrology, it may be possible that larger regions and areas substantially removed from drilling sites may experience impacts, which may emerge only after years or decades. A key question, therefore, is how much of a risk to America's water are we willing to tolerate in order to develop unconventional natural gas resources?



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Impacts on Terrestrial Habitats and Wildlife

The Nature Conservancy of Pennsylvania estimated that an average of 8.8 acres is required for each drilling pad in the Marcellus Shale region, including the area needed for storage facilities.[33] While the impact of a single drilling operation may not be enormous, the cumulative impact of many drilling locations can add up. Many thousands of wells may be drilled in regions to be developed for shale gas.

Drilling pads also require access roads, which may need to be newly constructed, along with waste pits. To transport the natural gas that is produced to end users, pipelines need to be built, as well as compressor stations, storage tanks and other facilities.

The cumulative effects of all of these activities can leave a large footprint on the landscape, reducing the available habitat for certain species. Wildlife species that depend on forest ecosystems can be impacted by the fragmentation of forested areas. Disruptions can affect areas beyond that taken up by the infrastructure itself; many wildlife species avoid cleared areas, and the "edge effects" of new clearings can prevent species from entering areas they previously used, and can also allow invasive species to displace native ones.

While the drilling of multiple horizontal wells from a single drilling pad has the advantage of potentially reducing the overall surface area required for drilling operations, the impact on the land is still significant. In the report "Pennsylvania Energy Impacts Assessment," The Nature Conservancy of Pennsylvania projected that 60,000 natural gas wells will be drilled over the coming two decades in the Marcellus Shale area of Pennsylvania,[34] in addition to the more than 3,000 drilled already. The organization projected that this would result in the clearing of 33,800 acres of forest, and that "Indirect impacts to adjacent forest interior habitats would total an additional 81,500 acres."[35]

Drilling activities can also negatively impact species dependent on habitats outside of forests. In determining whether the greater sage-grouse warranted protection under the Endangered Species Act, the United States Fish and Wildlife Service concluded that oil and gas drilling in western sagebrush habitats poses a serious threat to the viability of the species.[36] On the Pinedale Anticline in western Wyoming, researchers have documented a 60% drop in mule deer populations in areas impacted by gas drilling operations.[37]

Wildlife and their habitats can also be harmed by the discharges of water that accompany drilling operations. Fracking fluids can be deadly to plants. An experiment was conducted by a soil scientist with the U.S. Forest Service in which 75,000 gallons of fracking fluids were applied to the ground in a forested area one-quarter acre in size; this resulted in the death of much of the area's plants.[38] According to the abstract for this study,

> "During application, severe damage and mortality of ground vegetation was observed, followed about 10 [days] later by premature leaf drop by the overstory trees. Two years after fluid application, 56% of the trees within the fluid application area were dead."

Fracking fluid spills have also impacted animals. In 2009, 17 cows were reported to have died in Caddo Parish, Louisiana, after rains washed fracking fluid into their grazing area.[39] Studies apparently have not been conducted to determine the effects on wildlife of contact with fracking fluids; wildlife would clearly be at risk from spills of fracking fluids or exposure to pits holding fracking flowback water, in which they could also become trapped. Wildlife and pets are known to be attracted to ethylene glycol, a common component of fracking fluids; ingestion can cause death.[40] While wastewater


iStockphoto

from natural gas drilling activities has reportedly been used in some areas for dust suppression and de-icing of roads,[41] intentionally spreading or spraying such wastewater on roads or vegetated areas would be expected to detrimentally impact flora and fauna.

The several hundred truck trips that may be required for the entire drilling process at a single well, as well as the noise and light from machinery, can also impact wildlife, disrupting and impeding their breeding and feeding activities.

Natural gas is highly flammable and also poses an explosion hazard. Accidents involving natural gas pipelines can be deadly. On September 9, 2010, a natural gas pipeline exploded in San Bruno, California, killing at least eight people. There have also been explosions at drilling sites, as occurred in February 2011 at a natural gas drilling site in Washington County, Pennsylvania.[42] After the immediate effects of a rupture of a natural gas well or pipeline, natural gas will dissipate into the air, unlike oil; spills of oil often require expensive clean up operations and can lead to significant harm to the marine environment or to rivers that serve as wildlife habitat and water sources for agriculture or human consumption. Nevertheless, natural gas explosions or fires could set off forest fires, especially in arid regions.

Given the novel and complex nature of shale gas development, and the fact that inexperienced landowners will be involved in granting rights for drilling operations on their land, it will be especially important that the regulatory framework err on the side of caution. A team of U.S. Forest Service scientists worked with a company that was going to drill at the Fernow Experimental Forest in West Virginia, seeking to minimize the environmental impacts of the drilling – yet even these experts concluded that they could not manage and anticipate all of the related impacts. They wrote,

Gary Kramer/USFWS

"The unexpected will always happen, and should be part of any planning discussions. The unexpected did occur during the development of the gas well and pipeline on the Fernow. We attribute such occurrences to accidents, equipment failures, and misconceptions about what to expect ...Discussions of the process between the energy developer and the landowners/managers should happen early and often to be sure that all parties' expectations are clear...While we recognize that it is impossible to foresee every eventuality, we suggest that a thorough analysis of risks to natural resources, using alternative 'what-if' scenarios, should be conducted.

"Much more research is needed immediately to better understand and predict the effects of natural gas exploration and development on forests, particularly in the eastern United States. We were surprised by the paucity of peer-reviewed research evaluating effects of natural gas development on forest lands in the eastern United States...We also know little about the effects of exploration and development on ground water hydrology and water quality, and surprisingly little about effects on downstream surface waters. In general, information about effects on most fauna also is lacking..."[43]

The impacts on land, ecosystems and wildlife depend on the specific geology, watersheds, and proximity to habitat for wildlife and rare species. Nevertheless, such impacts should be considered whenever unconventional gas development is planned or pursued.

Impacts on Air Quality

The use of natural gas should be seen in comparison to other competing methods of electricity production. Using natural gas can improve air quality if it can replace the use of other fossil fuels that are more polluting.

Natural gas is composed mainly of methane, along with other hydrocarbon impurities – including butane, ethane and propane – and tends to have far fewer impurities that can cause air pollution

The use of natural gas for electricity generation is growing, which can be good for air quality, if natural gas power plants can supplant highly-polluting coal-fired electricity generating plants. In comparison to the burning of coal, the burning of natural gas results in far lower emissions of sulfur oxides (which contribute to acid rain), particulates and mercury. Natural gas combustion also results in lower emissions of volatile organic compounds and nitrous oxides, which contribute to the formation of the pollutants ground-level ozone and photochemical smog, and can lead to respiratory ailments.

Focusing on the air quality impacts of natural gas *combustion* does not tell the whole story, however. The *extraction* of unconventional natural gas can also create short- and long-term air quality problems that can impact the health of people and wildlife. Drilling rigs and gas compressor stations may involve the use of machinery, often powered by diesel generators, producing exhaust resulting in noxious odors and air pollution, including emissions of volatile organic compounds and nitrogen oxides, which contribute to regional ozone and smog levels.

The expansion of shale gas drilling is expected to increase ozone and smog levels in areas of the country that have not had to deal with this problem before. For example, despite its rural character, Wyoming's Upper Green River Basin experienced ozone pollution levels in March 2011 that were higher than levels of this pollutant that had been recorded in the dense urban area of Los Angeles at any time during the previous year.[44] Such air pollution can impact human health by exacerbating asthma and other respiratory ailments, and can also be expected to impact wildlife.

Clearly, if the industry fails to rein in pollution, there will likely be strengthened and ongoing opposition to unconventional natural gas extraction activities. Cleaning up this air pollution is not only essential, but can even be done at low cost. In July 2011, the Environmental Protection Agency proposed an updated set of air quality standards for the oil and gas industry that would reduce smog-creating volatile organic compounds and other pollutants.[45] The EPA concluded that significantly cleaning up these air pollutants would actually result in a net savings to the industry, while at the same time significantly reducing risks of respiratory problems and cancer.

Impacts on Greenhouse Gas Emissions

Another impact on our atmosphere is greenhouse gas emissions. Greenhouse gases (GHGs) are those gases in the atmosphere — including water vapor, carbon dioxide, methane and chlorofluorocarbons — which block infrared radiation and thereby prevent heat from radiating into space. Increased concentrations of GHGs in Earth's atmosphere are expected by climate scientists to lead to increasing global temperatures and associated changes in climatic conditions, including more severe droughts, rainfall and heat waves. Such changes combine with habitat destruction and other threats to plants and animals, which can eventually lead to population declines and extinction of some species.[46]

Natural gas is mainly made up of methane; when burned, methane combines with oxygen in the air and is chemically converted to carbon dioxide and water vapor. The burning of natural gas results in lower emissions of carbon dioxide than burning other fossil fuels to produce the same amount of energy; natural gas has roughly one-half of the carbon dioxide emissions of coal on an energy-output basis.[47]

Focusing solely on the effects of combustion, numerous studies have concluded that replacing coal-fired power plants with natural gas-fired plants would help to reduce greenhouse gas emissions, all other things being equal. An MIT study found that switching over older coal-fired power plants to efficient natural gas power generation could decrease total U.S. carbon dioxide emissions by 8%.[48] Natural gas plants can also be more efficient overall than coal plants; new "combined cycle" power plants, which burn natural gas and also utilize the turbine exhaust to power a generator, are a particularly attractive approach to electricity generation.

However, a full life-cycle analysis of competing energy sources is necessary before reaching any conclusions about the greenhouse gas benefits of a transition from coal to natural gas. This is because methane is itself a potent greenhouse gas, and leakages of unburned methane from storage equipment and pipelines contribute to a higher overall life-cycle "greenhouse gas footprint" for natural gas as an energy source. If such unintentional releases, known as "fugitive emissions," are high, the overall greenhouse gas footprint of natural gas may in fact be worse than that of other energy sources. A study by researchers from Cornell University estimated that 3.6% to 7.9% of the "methane from shale-gas production escapes to the atmosphere in venting and leaks over the lifetime of a well."[49] Fugitive methane emissions are believed to be higher for shale gas than for conventional natural gas production,[50] specifically as a result of the hydraulic fracturing process, because methane can become mixed with the drilling flowback water, which reemerges above ground, where the methane can enter the atmosphere. The drilling process to reach deep shale gas deposits may also involve puncturing shallower reservoirs of methane, which can then seep out of the drill hole.

The amount of methane that is released at the various steps in the extraction and delivery process is not known. Even if the total amount of methane released through unconventional natural gas drilling activities could be known with certainty, assessing the lifecycle

greenhouse gas impact of natural gas in comparison to that of other fossil fuels requires an arbitrary determination of the time-span that is to be considered. Methane has a "global warming potential" (GWP) that is far greater than that of carbon dioxide (that is, a given mass of methane traps a total amount of infrared radiation equivalent to many times the same mass of carbon dioxide; by definition, the GWP for carbon dioxide is 1.0 for all time spans). According to the United Nations Framework Convention on Climate Change, over a 20-year time span, the GWP of methane is 56[51] and over a 100-year time span it is 21. However, a new estimate indicates that the GWP of methane may be as high as 105 on a 20-year time span and 33 on a 100-year time span.[52] The Cornell study suggests that over a short time span, such as 20 years, the GHG footprint of unconventional gas is significantly greater than that for conventional gas.[53] The conclusions of this study are very preliminary, and the researchers acknowledge that further research is needed.


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Unfortunately, the lifecycle greenhouse gas emissions associated with unconventional gas drilling are an area for which very little research has been conducted. It would be important to fully understand this important impact before promoting further natural gas extraction, as this could be contrary to the goal of reducing GHG emissions, if methane emissions are in fact as high as some estimate.

In addition to research on the lifecycle greenhouse gas impacts of fuels, much more research is urgently needed to develop systems for monitoring and eliminating fugitive methane emissions from natural gas infrastructure. Many technologies exist – such as reduced-emission valves – that can reduce methane emissions. Placing a high priority on the fugitive emissions issue can help spur the development and use of monitoring and control technologies to reduce overall GHG emissions.

Conclusion

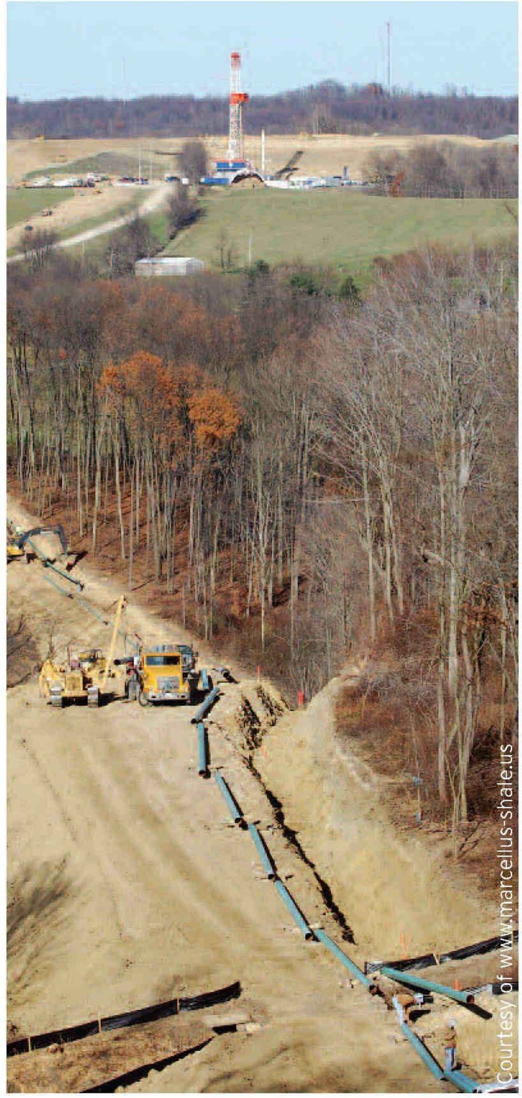
All energy development activities have environmental impacts; we should pursue those energy options that are the least damaging to human health and the environment, including habitats and wildlife.

Unfortunately, natural gas exploitation is taking place today in a rushed manner, before all of the needed environmental safeguards have been properly put in place, including adequate inspection systems and monitoring procedures.

Because unconventional natural gas development currently is proceeding without the full range of needed environmental safeguards, the natural gas that is being produced is cheaper than it would be if the full social and environmental costs of drilling were to be included. Current development activities are therefore fueled by a distorted sense of outsized future profits and underappreciated costs for ensuring safe operations that do not harm the environment. Such artificially cheap natural gas can undercut investors' support for renewable energy sources, such as wind and solar, which produce far less pollution.

Utilizing unconventional natural gas resources may in some cases be less damaging to the environment than utilizing other energy sources, such as tar sands, coal obtained through mountaintop removal mining, and oil from offshore drilling. Nevertheless, natural gas is a fossil fuel, one that results in emissions of the pollutants linked to global warming. It is also a resource that may be effectively depleted over coming decades; it is therefore no more than a temporary solution to our nation's energy needs.

Because natural gas will be a component of our energy future, America should choose extraction practices that do not endanger the long-term integrity and health of our forests, rivers and grasslands, and the wildlife species that depend on these habitats. A system of responsible environmental regulations and safeguards should be put in place to ensure that any exploitation of unconventional natural gas resources is conducted in a manner that will minimize environmental impacts and which will garner the trust of the public and be of long-term benefit to communities.


Courtesy of www.marcellus-shale.us


Courtesy of EcoFlight

Recommendations — Toward a Responsible Policy Framework

The potential environmental and health risks of natural gas exploitation are real and must be addressed. The exploitation of unconventional natural gas resources is currently being pursued with insufficient public access to related information, and without the necessary research and monitoring taking place. The public needs more information, more participation in decisions, and for more safeguards to be put in place.

Natural gas development, transportation, processing and use must avoid, minimize and mitigate (in that order of priority) any potential damage to wildlife habitat and air and water quality. If delays in projects are required before such a framework can be put in place, then that is a small price to pay for safeguarding our nation's land, air, water and wildlife.

To ensure that the development of unconventional gas resources is done in an environmentally responsible manner, National Wildlife Federation recommends that unconventional natural gas resource development should proceed in keeping with a set of responsible environmental safeguards and regulatory frameworks. These should include:

- **Ensuring Transparency**
  The potential risks justify complete transparency and full public disclosure of all of the components of fracking fluids and their concentrations, as well as information regarding all other aspects of drilling operations that may impact the environment. Some states have recently passed laws to improve fracking chemical disclosure, but they allow for the exemption of "trade secret" items.[54] FracFocus, a new website for voluntary disclosure has been set up by the industry and lists those chemicals mandated for reporting by OSHA,[55] but all fracking operations should be mandated to report all of the components and concentrations of the chemicals used in fracking fluids. For this purpose, the FRAC Act (Fracturing Responsibility and Awareness of Chemicals Act), which ends the exemptions for drilling operations under the Safe Drinking Water Act, should be enacted.[56]

- **Improving Research and Monitoring**
  There is not enough information about the impacts, especially cumulative impacts, of hydraulic fracturing operations and unconventional natural gas exploitation. A comprehensive national program for research should be instituted, along with comprehensive monitoring of drilling operations by local, state and federal agencies. Independent audits of impacts should be supported and funded. A program for monitoring of methane leakages should be instituted, and support should be enhanced for the EPA's Natural Gas STAR Program, which promotes the adoption of technologies and practices that reduce methane emissions.[57] Research into mechanisms of methane contamination of groundwater and baseline surveys of water quality before drilling activities should be the norm. There should also be increased research on the potential impacts on wildlife and habitats from drilling activities.

- **Eliminating Loopholes and Exemptions**
  Fracking and drilling operations have been exempted from certain provisions of key laws that have been established to protect our nation's water and environment. The exemption under the Safe Water Drinking Act of regulation of fracking fluids injected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underground should be removed. Fracking fluids should be categorized as industrial waste, unless operators can prove that their composition does not include toxic chemicals. There should be no exemptions in environmental laws for drilling operations; the existing Storm Water Runoff Loophole under the Clean Water Act and the air pollution exemptions that currently exist under the Clean Air Act should also be removed.

- **Establishing Mitigation and Compensation Mechanisms**

  If contamination of water resources or other major impacts occur, it will be essential for those affected to be able to be properly compensated, and for cleanup operations to be undertaken. Proper investigations should be mandated for any cases of water contamination in areas of shale gas extraction; this could be funded through state or federal funding mechanisms established through fees on drilling. Appropriate mechanisms for funding such activities should be mandatory in resource development areas. As it may not always be possible to establish cause and effect relationships for impacts that occur underground, and the responsibility of drilling companies for contaminating drinking water wells, innovative compensation mechanisms, such as state or federally backed compensation funds, could be contemplated. The principle of presumptive liability, under which cases of groundwater contamination in the vicinity of drilling operations are assumed to be caused by drilling activities, should be legislated.[58] Companies should also be required to include chemical markers that will allow for tracking the sources of contamination back to specific drilling operations. Adequate local impact fees, which will allow authorities to address environmental and community needs, and to deal with problems that may arise, should be assessed on drilling operations. Companies should also be required to fund activities to mitigate impacts on habitats resulting from the development of drilling pads and other infrastructure.

- **Reducing the Impact of Drilling on Water**

  More environmentally friendly mixtures of fracking fluids have been developed, such as those not requiring toxic chemicals.[59] These kinds of improved fluid mixtures should be used throughout the industry and the industry should move swiftly away from the use of any chemicals that are highly toxic to humans or wildlife. Although gas yields may be slightly lower, and costs slightly higher, the benefits that will accrue in terms of safeguarding water resources will be well worth it.

  Water use plans should be developed to ensure that drilling and related operations do not negatively impact water resources and other water uses; "cradle-to-grave" water tracking systems should be the norm. Emergency response and remediation plans, including strict spill prevention and management plans, should be developed for each site prior to any drilling operations, based on industry best practices for construction and lining of pits. Water withdrawals for natural gas operations should ensure adequate stream flows for fish and other wildlife. Waste water recycling and reuse should take place whenever possible. To prevent erosion and silting of water bodies, properly installed and maintained silt fences should be required, and drilling operations should not be exempted from relevant regulations, such as those requiring regulation of stormwater runoff.

- **Reducing the Impact of Drilling on Habitats**

  Wildlife surveys should be conducted prior to the initiation of drilling operations; drilling pads and infrastructure should be sited so as to maintain the ecological integrity of important wildlife habitats and to minimize potential impacts on habitats and species. Adequate minimum setbacks from surface water resources should be ensured. Drilling plans should be

based on reducing the area of habitat that will be converted or fragmented. Activities to restore drilling sites after well closures should be designed and monitored to ensure that they adequately restore native vegetation and habitats.

- **Reducing the Impact of Drilling on Air Quality**

  The proposed improvements to EPA air quality standards, including for hydraulic fracturing and natural gas transportation infrastructure (including compressors, storage tanks and other components), should be adopted and enforced in a stringent manner. Efforts to reduce emissions of the air pollutants that contribute to global warming should be strengthened, including through applying in a mandatory fashion the best practices that have been developed under voluntary programs for capturing fugitive methane emissions.

- **Safeguarding Parks, Tribal Lands and Other Special Areas**

  Many publicly-owned lands and tribal lands require special planning processes and protections from drilling operations for aesthetic, cultural, and ecological reasons, as well as to ensure that the precious landscapes and critical habitats they contain can be preserved, and so that revenues from tourism and recreation are not negatively impacted. Drilling should not be allowed in parks and areas of high conservation value. Areas with particularly sensitive wildlife habitat or having other important conservation and aesthetic value may be inappropriate for natural gas extraction or other energy development activities. Environmental and wildlife organizations have called for the exclusion of certain federal public lands from drilling activities, including the Roan Plateau in Colorado, Otero Mesa in New Mexico, Book Cliffs in Utah and the Rocky Mountain Front in Montana,[60] as well as the George Washington National Forest.

- **Promoting Clean, Renewable Energy Sources**

  Fossil fuels will eventually be depleted. Preference should therefore be given to energy conservation and energy sources that are renewable. All government subsidies and preferential incentives for oil, gas and coal production should therefore be removed.

- **Improved Oversight and Inspections**

  Standards, regulations and monitoring should be strengthened. To minimize accidents and pollution, the permitting process should be reviewed to identify procedures to prevent drilling-related activities that could lead to environmental damage. Permits should be required for all stages of the drilling process, based on strict environmental and safety criteria and procedures, including reviews by specialists trained in minimizing environmental hazards, as well as studies of surface and subsurface water flows and chemical composition (thus providing a baseline against which potential contamination can be measured). All operations should be inspected, including through unannounced inspections; all information gathered during such inspections should be made available to the public. Ongoing sampling of surface water and groundwater quality, as well as air quality, should be undertaken, with results made publicly available. Oversight and inspections should be fully funded by the natural gas industry and by the producers themselves.

- **Public Involvement**

  Communities, residents and other stakeholders (such as natural resource user groups, including hunters and anglers) in areas where unconventional natural gas exploitation is planned or contemplated should always be fully informed of all procedures to be undertaken, and should have sufficient opportunities to review and provide public comments on any related plans.

Endnotes

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[55] "Frequently Asked Questions." *FracFocus Chemical Disclosure Registry*. Ground Water Protection Council and the Interstate Oil and Gas Compact Commission, 2011. Web. <http://fracfocus.org/faq>. This website notes that "Only wells fractured after January 1st will be entered into the system."

[56] In mid-August 2011, as this report was being written, a special advisory committee established by the Department of Energy issued a set of draft recommendations, including for disclosure of chemicals used in fracking. The final report of this committee was scheduled for release on November 18, 2011. See *The SEAB Shale Gas Production Subcommittee Ninety-Day Report*. Working paper. Shale Gas Subcommittee of the Secretary of Energy Advisory Board, 11 Aug. 2011. Web. <http://www.shalegas.energy.gov/resources/081111_90_day_report.pdf>. P. 3.

[57] "Natural Gas STAR Program- Basic Information." *US EPA*. United States Environmental Protection Agency. Web. <http://www.epa.gov/gasstar/basic-information/index.html>.

[58] A recommendation of the Marcellus Shale Advisory Commission in Pennsylvania in July 2011 was to "Extend a well operator's presumptive liability for pollution or water loss from 1,000 feet to 2,500 feet." See Swift, Robert. "Shale Panel Recommends Generic Impact Fee." *Citizensvoice.com*. The Citizens' Voice, 16 July 2011. Web. <http://citizensvoice.com/news/drilling/shale-panel-recommends-generic-impact-fee-1.1176001#axzz1STO5UKEe>.

[59] Examples include the "CleanStim® Hydraulic Fracturing Fluid System" (see "CleanStim® Hydraulic Fracturing Fluid System - Halliburton." *Halliburton*. Halliburton. Web. <http://www.halliburton.com/ps/default.aspx?pageid=4184>) and "The BJ SmartCare System" (see "The BJ SmartCare System." *Bakerhughes.com*. Baker Hughes, Inc. Web. <http://public.bakerhughes.com/ShaleGas/collateral/31157.SmartCare_PO_1210.pdf>.)

[60] *Hunting and Fishing Imperiled*. Rep. Sportsmen for Responsible Energy Development, 2008. Web. <http://www.sportsmen4responsibleenergy.org/FullTextReport.pdf>.

National Wildlife Federation
11100 Wildlife Center Drive
Reston, VA 20190
703-438-6000
www.nwf.org

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